The Nucleus-Nucleus Proximity Potential and Superheavy Nuclei*

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The proximity potential [1] provides a simple formula for the nucleus-nucleus interaction energy as a function of the separation between the surfaces of the approaching nuclei. However, in order to relate the separation between the nuclear surfaces to the distance between the centers of the approaching nuclei one needs, in addition, an accurate expression for the relevant nuclear radii.

In the past 25 years considerable progress has been made in the accurate determination of nuclear properties, including the surface energy coefficient and nuclear radii. Using such up-to-date values of nuclear parameters, the present paper re-analyzes the confrontation of the proximity barriers with the 1981 set of measurements in [2], as well as with more recent data. The result is that a 4% discrepancy between theory and measurement is no longer present.

In the second part of the paper we present an application of the proximity treatment to a discussion of recently measured cross-sections for the synthesis of very heavy nuclei.

The calculated proximity barriers, when applied to fusion reactions used to produce heavy elements with atomic number Z = 102–118, suggest that the unexpectedly large cross-section observed in the reaction ^{86}Kr +^{208}Pb → ^{293}118 + 1n [3] may be due to the sinking of the Coulomb barrier below the level of the bombarding energy.

The energy needed to deform a compound nucleus into two tangent fragments is resisted by the surface energy and favoured by the Coulomb energy. Hence, the greater the charge on the compound nucleus, the lower the Coulomb barrier. Above some critical charge the Coulomb barrier will sink below the ground-state energy.

Is it really true that the unshielding in the ^{86}Kr+^{208}Pb reaction is responsible for the enhancement of the corresponding cross-section by some four orders of magnitude with respect to a simple extrapolation? It turns out that it should not be too difficult to make an experimental test of this conjecture. Thus, element 112 was produced with a picobarn cross-section at the GSI laboratory in the shielded reaction ^{70}Zn+^{208}Pb = ^{278}112 = ^{277}112 + 1n. [4] The identical isotope can be reached in the unshielded reaction
^{136}Xe + ^{142}Ce = ^{278}112 = ^{277}112 + 1n.
Will the cross-section be one or more orders of magnitude higher!?

A similar test of the unshielding hypothesis would consist of comparing the shielded reaction ^{58}Fe + ^{208}Pb = ^{266}108 (which produced ^{267}108 with a peak cross-section of about 70 picobarns [9]) with the unshielded reaction ^{128}Te + ^{138}Ba = ^{266}108.

Unshielded reactions, if proved beneficial, would open a broad avenue for making several new elements and many new isotopes in the region of Z > 104. In particular, the prospect for reaching the island of superheavy nuclei around N=184 and Z=114–126 would be much improved.

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